ELF EMF Assessment

FOR:

PDS Group
Level 1, 63 York Street
Sydney, NSW 2000

PROJECT:

Frasers Eastern Creek Retail Centre
Corner of Beggs Road & Rooty Hill Road South
Eastern Creak, NSW 2766

REPORT: **F1404**
DATE: July 2017

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Project Details:
Frasers Eastern Creek Retail Centre
Corner of Beggs Road & Rooty Hill Road South
Eastern Creak, NSW 2766

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Specification:
National Health & Medical Research Council (NHMRC)
Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields (1989), Radiation Health Series No.30.

AS/NZS™ 61000.6.1:2006 Electromagnetic Compatibility (EMC) Generic standards – Immunity for residential, commercial and light-industrial environments

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19/09/2017

Darek Ocias (Project Engineer) — John Kennett (Project Manager) — Date

REVISION HISTORY

Revision	Issue date	Changes
Draft	18/072017	
Draft 2	18/09/2017	Removed: references to specific magnetic shielding requirements
		Fully revised: Section 8
		Updated: Fig. 1a in Appendix A
		Removed: Appendix B, Shielding Requirements
0	19/09/2017	

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Contents

SUMMARY

A new Retail Centre is to be constructed at the corner of Beggs Road & Rooty Hill Road South, Eastern Creek, NSW. The development comprises of a 40,000m^2 "large format" retail, and 10,000m^2 general retail precinct incorporating specialist shops and services.

Faraday Pty Ltd was engaged to estimate 50Hz magnetic emissions from electrical services, and provide advice on magnetic shielding.

A typical method based on Ampere's Law was used to calculate the magnetic field generated by a 50Hz current flow in electrical cabling.

Where no information was available, standard assumptions as listed in section 6 of this report were applied during the estimation process.

The calculated values were compared with:

- 100µT, National Health & Medical Research Council limit
- 3.75µT limit value in case of electronic equipment exposures.
- 1µT magnetic field level - industry benchmark limiting exposure of humans to power frequency magnetic field within long term occupancy areas
- 0.4µT limit for children suggested by the UK National Radiological Protection Board Advisory Group on Non-Ionising Radiation (AGNIR)

Due to the limited information on the electrical cabling distribution and/or the designation of areas of concern, the report does not specifically recommend shielding. The following measures are suggested to reduce magnetic emissions from electrical services:

- increasing distances between electrical services and the areas of concern
- implementation of low emissions phase configuration for major cables distributed from the main switchrooms.

More information is required on the areas of concern and the electrical system to give detailed advise on the magnetic shielding.

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1. SCOPE

Faraday Pty Ltd was engaged to:

- provide advice on acceptable Extremely Low Frequency (ELF) Electromagnetic Field (EMF) exposure levels
- estimate magnetic emissions from the in-building major electrical services
- provide advice on shielding requirements if and where necessary.

2. UNITS

For the purpose of this report, the magnetic flux densities have been expressed in Tesla, abbreviated as T.

Note that the older unit, used prior to year 1988 (when full transition from the Imperial to the International System of Units, SI, occurred in Australia), was Gauss - abbreviated as Gs or G:

1 T = 10 kGs	1 kGs = 0.1 T	1 T = 10^6 µT
1 mT = 10 Gs	1 Gs = 0.1 mT	1 µT = 10^3 nT
1 µT = 10 mGs	1 mGs = 0.1 µT	1 nT = 10^{-3} µT
1 nT = 10 µGs	1 µGs = 0.1 nT	

3. REGULATIONS

3. 1 Human exposure to power frequency magnetic field

Currently there is no standard in Australia regulating human exposure to power frequencies electromagnetic field.

3.1.1 In December 2006 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) released the draft *Radiation Protection Standard: Exposure Limits for Electric and Magnetic Fields 0Hz – 3kHz*. The standard, however, has not been ratified to date.

3.1.2 Human exposure to power frequency magnetic fields is currently regulated by the National Health and Medical Research Council (NHMRC) *Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields (1989), Radiation Health Series No.30*.

3. 2 Electronic and electrical equipment exposure to magnetic fields

The following standards regulate exposure to power frequencies magnetic field for general and electronic and electrical equipment:

- Australian and New Zealand standard *AS/NZS™ 61000.6.1:2006 Electromagnetic Compatibility (EMC) Generic standards – Immunity for residential, commercial and light-industrial environments*

4. EXPOSURE LIMITS

4. 1 Human exposure limits

4.1.1 The NHMRC guidelines recommend the following limits of exposure to the power frequency magnetic field:

- *members of the general public should not be exposed on a continuous basis to unperturbed magnetic flux densities exceeding 0.1mT. This restriction applies to areas in which members of the general public might reasonably be expected to spend a substantial part of the day*
- *for the general public, exposures to magnetic flux densities between 0.1mT and 1mT should be limited to a few hours per day. When necessary, exposures to magnetic flux densities in excess of 1mT should be limited to a few minutes per day*
- *continuous occupational exposure during the working day should be limited to magnetic flux densities not greater than 0.5mT*
- *short-term occupational whole body exposure for up to two hours per workday should not exceed a magnetic flux density of 5mT. When restricted to the limbs, exposures up to 25mT can be permitted.*

4.1.1.1 Concerns about the NHMRC values were already summarised in the NSW Government commissioned comprehensive report by Sir Harry Gibbs: *Inquiry into Community Needs and High Voltage Transmission Line Development (1991).*

The report outlines that the recommended exposure levels are well above the levels at which the fields may create a risk, as suggested in the guidelines. However, it should be recognised that the guidelines were established on the basis of instantaneous or short term exposure to the EMF. The limits, therefore, are not to be applied to the avoidance of a risk resulting from chronic exposures to power frequency electromagnetic fields.

4.1.1.2 The scientific report published in 2000 by the British Journal of Cancer, *A pooled analysis of magnetic fields and childhood leukaemia, 83(5), 692–698 (2000)*, suggests a statistical correlation between the time weighted long term average exposure level of 0.4µT and increased occurrences of childhood leukaemia.

4.1.1.3 The UK National Radiological Protection Board Advisory Group on Non-Ionising Radiation (AGNIR) accepted the BJC's report findings: *Power Frequency Electromagnetic Fields and the Risk of Cancer (2001).*

4.1.1.4 Due to increasing concerns about the effect of magnetic fields on people, a growing number of scientific and health organizations around the world tend to agree that the limit for continuous exposure to power frequency magnetic field should be set below 0.4µT time weighted average.

4.1.1.5 Considering the limit given above, a 24 hour continuous exposure to 0.4µT magnetic field is equivalent to 1.2µT exposure over an 8 hour (typical workday) period:

$$0.4\mu T \cdot 24 \text{ hours} \equiv 1.2\mu T \cdot 8 \text{ hours}$$

As it is impossible to guarantee no exposure to magnetic field after the 8 work hours, the calculated 1.2µT level needed to be reduced to 1µT. This allows for the additional continuous average exposure of 0.1µT during the rest of the day:

$$0.4\mu T \cdot 24 \text{ hours} \equiv 1\mu T \cdot 8 \text{ hours} + 0.1\mu T \cdot 16 \text{ hours}$$

4.1.2 The 1µT human exposure level can be considered as an alternative to the 100µT non-occupational limit prescribed by NHMRC. It has now become the industry benchmark for some applications.

4. 2 Electronic and electrical equipment exposure limits

4.2.1 *AS/NZS™ 61000.6.1:2006* sets the generic limit for immunity to power frequency magnetic fields as:

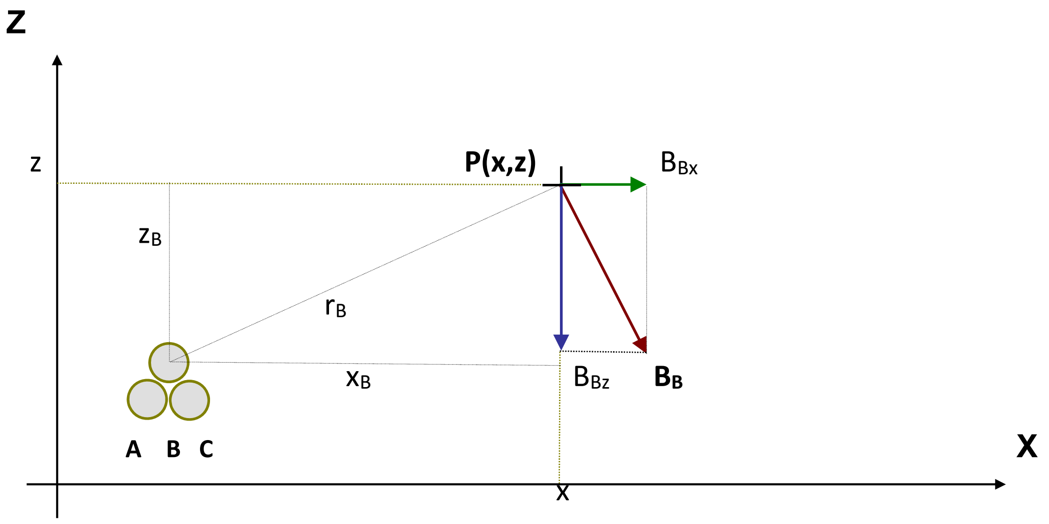
- 3A/m (equivalent to approximately 3.75µT) for all equipment
- 1A/m (equivalent to approximately 1.25µT) for magnetic deflection screen based equipment (ie Cathode-Ray Tube (CRT) Visual Display Units (VDUs).

5 MAGNETIC FIELD CALCULATION METHOD

The problem requires using of a typical method based on Ampere's Law.

The diagram below illustrates how the magnetic field surrounding the three phase electrical circuit is calculated.

The individual conductors, marked as **A**, **B**, and **C,** carry current in the **Y** direction therefore the only $\mathbf{B_x}$ and $\mathbf{B_z}$ field magnetic field components are calculated at point **P(x,z)**:



A, B, C, - current carrying conductors
P(x,z) - location of test point at co-ordinates (x,z)

$$\underline{B_x} = 0.2\sum_n \underline{I_n}\frac{z_n}{r_n^2} \qquad \underline{B_z} = -0.2\sum_n \underline{I_n}\frac{x_n}{r_n^2}$$

$$n = A, B, C \qquad r = \sqrt{z_n^2 + x_n^2} \qquad \underline{I_A} = I_{R.M.S.}$$

$$\underline{I_B} = I_A e^{-j\varphi} \qquad \underline{I_C} = I_A e^{j\varphi} \qquad \varphi = \frac{2\pi}{3},$$

$B = \left|\underline{B_x} + \underline{B_z}\right|$ represents the total magnetic field combined of the two components

6 ASSUMPTIONS

To facilitate the analysis it has been necessary to make the following assumptions:

- calculations are carried out for 50Hz component only
- phase angle remains constant at 120°
- calculations are carried out for the maximum expected phase currents
- all out-of-balance currents are returned through neutral conductors
- LV cable sets' conductors distributed from MSBs are in rectangular arrangement with phase conductors configured as prescribed in *AS/NZS3008.1.1:2009 Electrical installations - Selection of Cables - Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions* for triangular arrangement
- HV cable set's conductors are in flat configuration

- conductor's sizes are selected based on the expected maximum currents to be within 80% of conductors' capacity
- neutral conductors are capable of carrying all imbalances in the electrical system

6.1 Fault currents, in earth conductors are not included in the calculations.

6.2 No magnetic field attenuation factors resulting from neither equipment layout nor magnetic properties of materials surrounding the electrical services were incorporated into the calculations.

6.3 To determine the maximum current flowing through the LV terminals of the single transformer, the following formula was used:

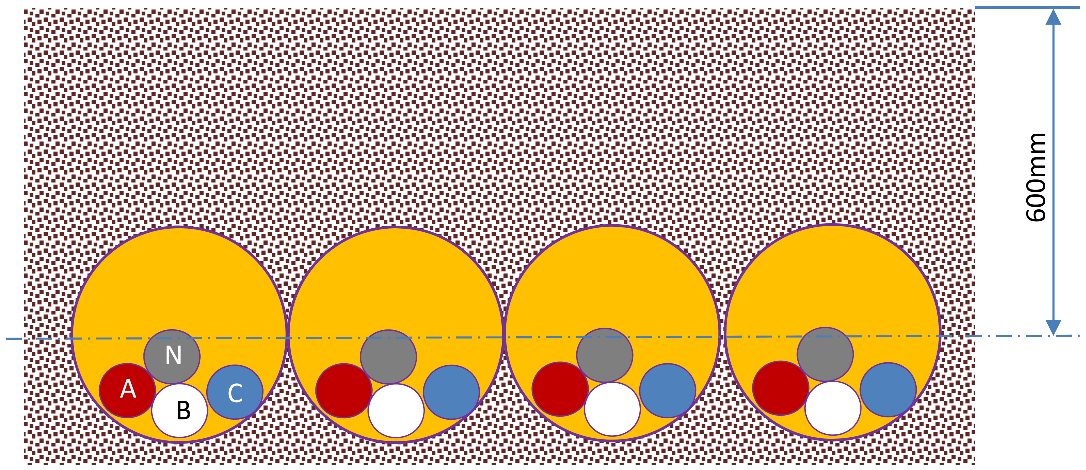
$$I_{II} = \frac{1000\ S\sqrt{3}}{3\ U_{II}}$$

where: I_{II} – current [A]
S – transformer's apparent power in [kVA]
U_{II} – secondary voltage [V]

For the given transformer parameters (1000kVA, 415V) a maximum of approximately 1390A can be expected at a single transformer's LV terminal.

6.3.1 There will be four conductors connected to each of the transformer's terminal. Each of the conductors will be carrying a maximum of approx. 347.5A electrical current.

The cabling running between transformers and MSBs will be placed in four 150mm PVC conduits located 600mm below ground as follows:



6.3.2 The LV cabling distributed from MSBs will be located not lower than 2.7m above floor.

6.4 To determine the maximum current in HV supply cables, the following formula was used:

$$I_I = \frac{1000\ S}{U_I\sqrt{3}}$$

where: I_I – current in [A]
S – apparent power in [kVA]
U_I – primary voltage [V]

For the given line and transformer parameters (22kV, 1000kVA) a maximum of approximately 26A can be expected in one phase of high voltage (HV) feeder cables.

Due to low current flow in HV cabling (less than 100A/phase), magnetic emissions from the cables were not calculated and can be ignored for the purpose of this report.

7 ESTIMATED MAGNETIC FIELD

The maximum magnetic field emissions which can be expected in the vicinity of the electrical services were estimated. Graphs of the estimated field are included in Appendix B as follows:

- Fig. 1b. Magnetic field generated directly above transformer's HV terminals (max. expected).
- Fig. 2b. Magnetic field generated directly above transformer's LV terminals (max. expected).
- Fig. 3b. Magnetic field generated above LV cables placed in PVC conduits (max. expected.
- Fig. 4b. Magnetic field generated above/under LV cabling leaving MSB (max. expected).

8 ANALYSIS / CONCLUSIONS / RECOMMENDATIONS

8.1 Considering that all three electrical substations are located well away from the Retail and Childcare Centers, emissions from the substations themselves will have negligible impact on the buildings' occupants.

8.1.1 Cables running in PVC conduits between the substations and the corresponding MSB rooms are not going to pass under occupied areas which would require protection from magnetic fields.

8.2 For the cabling distributed from the MSBs, depending on the area designation, magnetic shielding may be required to guarantee compliance with:

- AS/NZS™ 61000.6.1:2006 requirement of 3.75µT

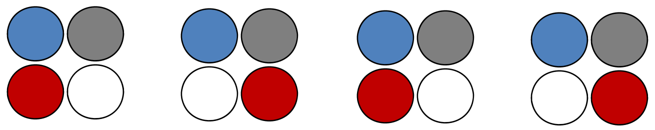
and, if desired, with:

- 1µT industry benchmark limit for human
- 0.4µT AGNIR limit for children.

8.2.1 Any shielding requirement depends on how the cables are routed, in terms of:

- distance to the areas of concern
- number of cable sets
- cables' arrangement (square/triangular)
- phases' configuration.

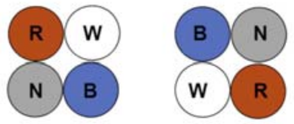
8.3 For the purpose of this report, the magnetic field generated by electrical currents flow in the overhead LV cabling was calculated considering a typical phase configuration for multiple single core cable sets arranged as follows:



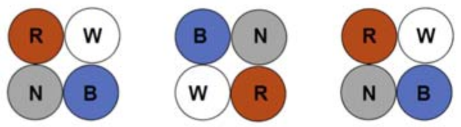
Note that the above configuration does not apply to the cables run in the PVC conduits, where it is impossible to maintain the above setup along entire cable path.

8.3.1 Configuring the conductors running between MSBs and MDBs as below will significantly reduce the peak magnetic emissions:

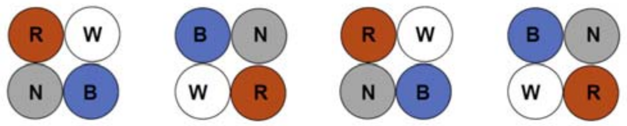
- in case of 2 cable sets



- in case of 3 cable sets



- in case of 4 cable sets



The field reduction will vary, depending mainly on the distance from the cables and current imbalances

8.3.2 It is strongly recommended to utilise the low magnetic emissions phase configuration, as described in section 8.3.1 of this report, for all three-phase single core cable sets distributed across the buildings from the LV Switchrooms. If implemented, this will reduce the shielding requirement by approximately 5dB or more.

8.3.3 Further reduction in magnetic emissions can be achieved by locating the electrical cable runs as far away from the areas of concern as possible.

The required distances, horizontal and vertical, may be established based on the magnetic field graphs included in Appendix B. This is in case of the typical cables' setup.

8.4 More specific information on the areas of concern is required to give precise shielding specification or for planning of cable routes.

8.5 No NH&MRC human exposure to 50Hz magnetic field limits will be exceeded within all areas accessible by general public across entire Retail & Childcare Centre area. This is including carpark.

APPENDIX A

Drawings

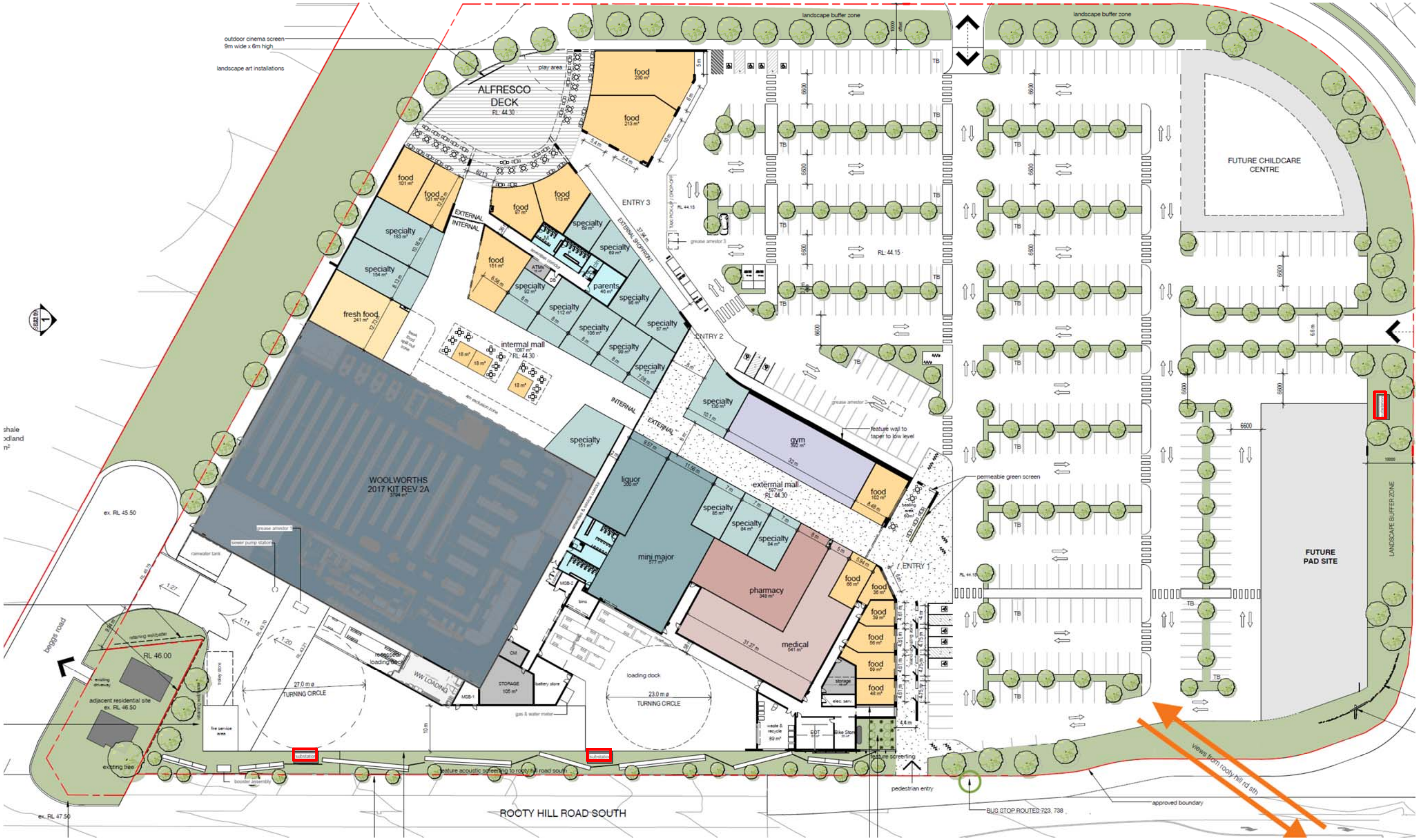
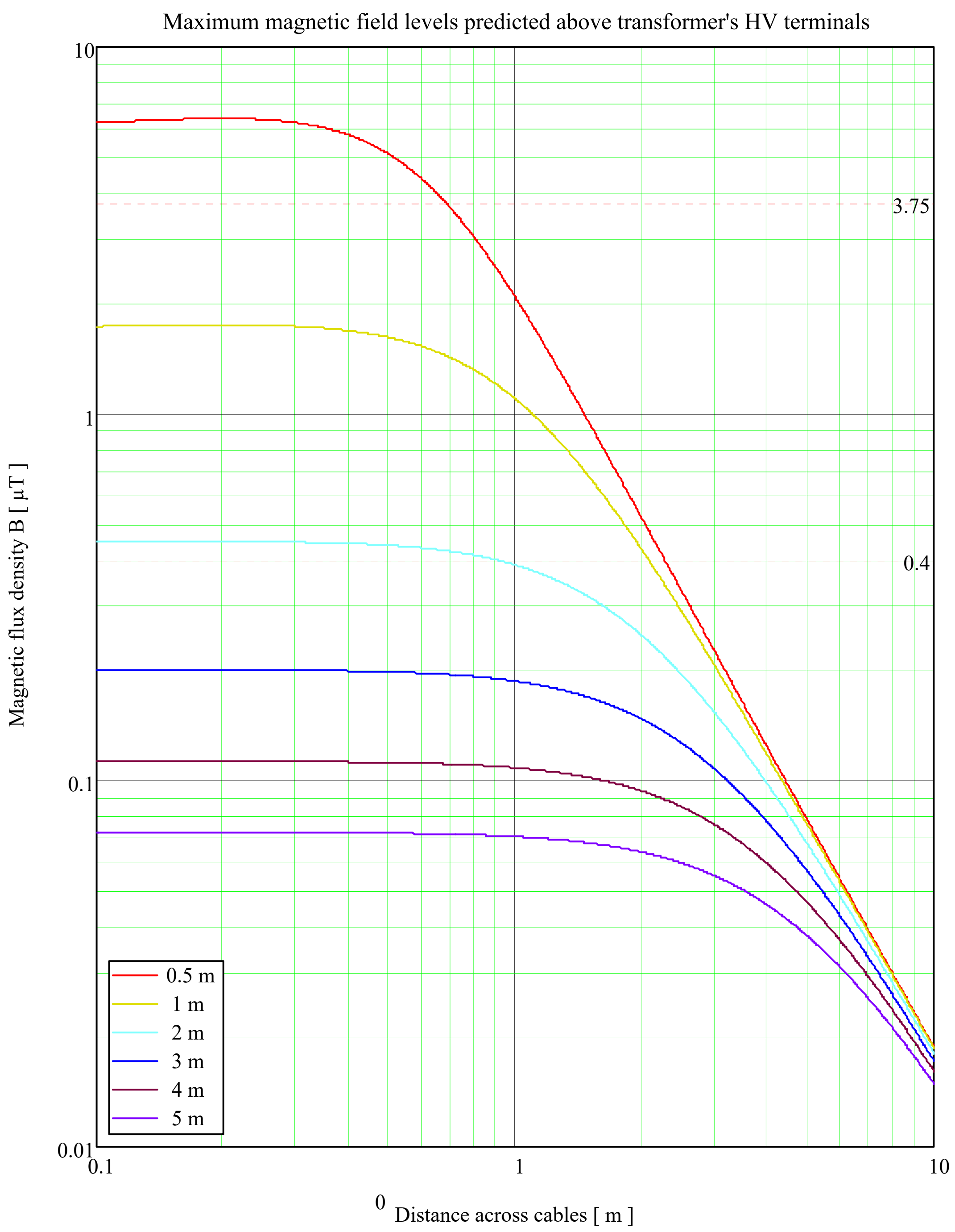


Fig. 1a. Eastern Creek Retail Centre Stage 1 site plan - (Extracted from DA05 Issue A, by i2C)

APPENDIX B

Magnetic Emissions Characteristics



1b. Magnetic field generated directly above transformer's HV terminals (max. expected).

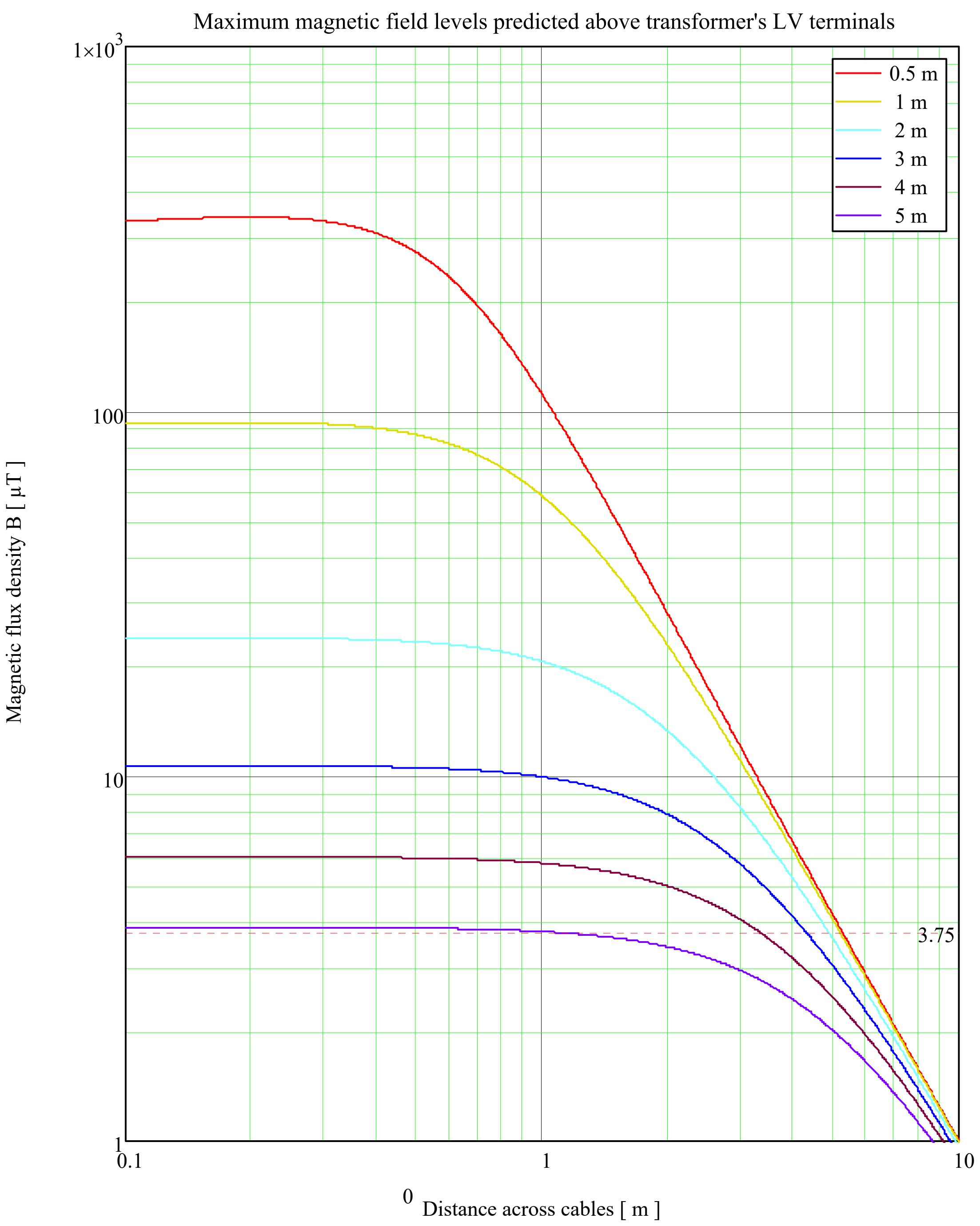


Fig 2b. Magnetic field generated directly above transformer's LV terminals (max. expected).

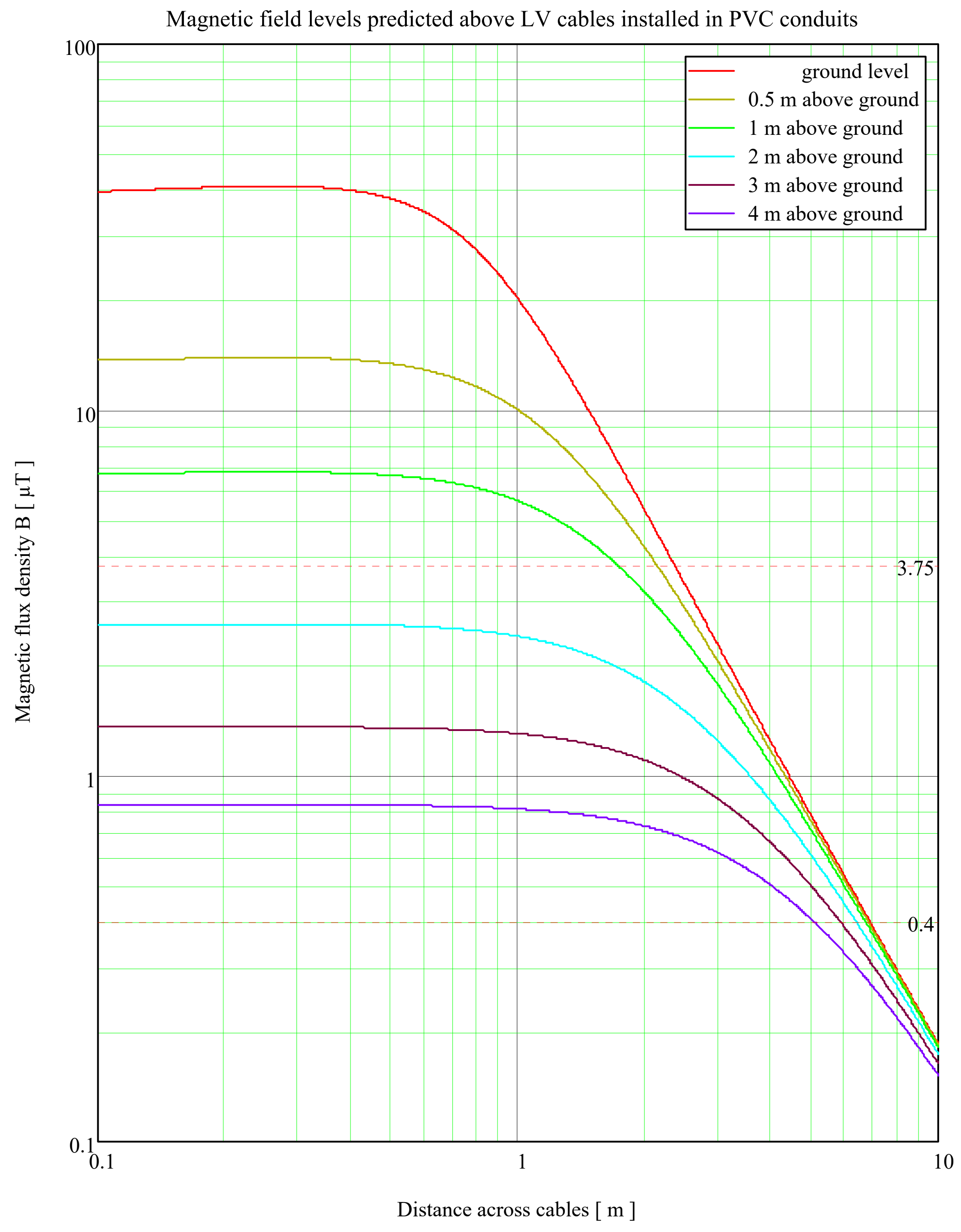


Fig. 3b. Magnetic field generated above LV cables placed in PVC conduits (max. expected).

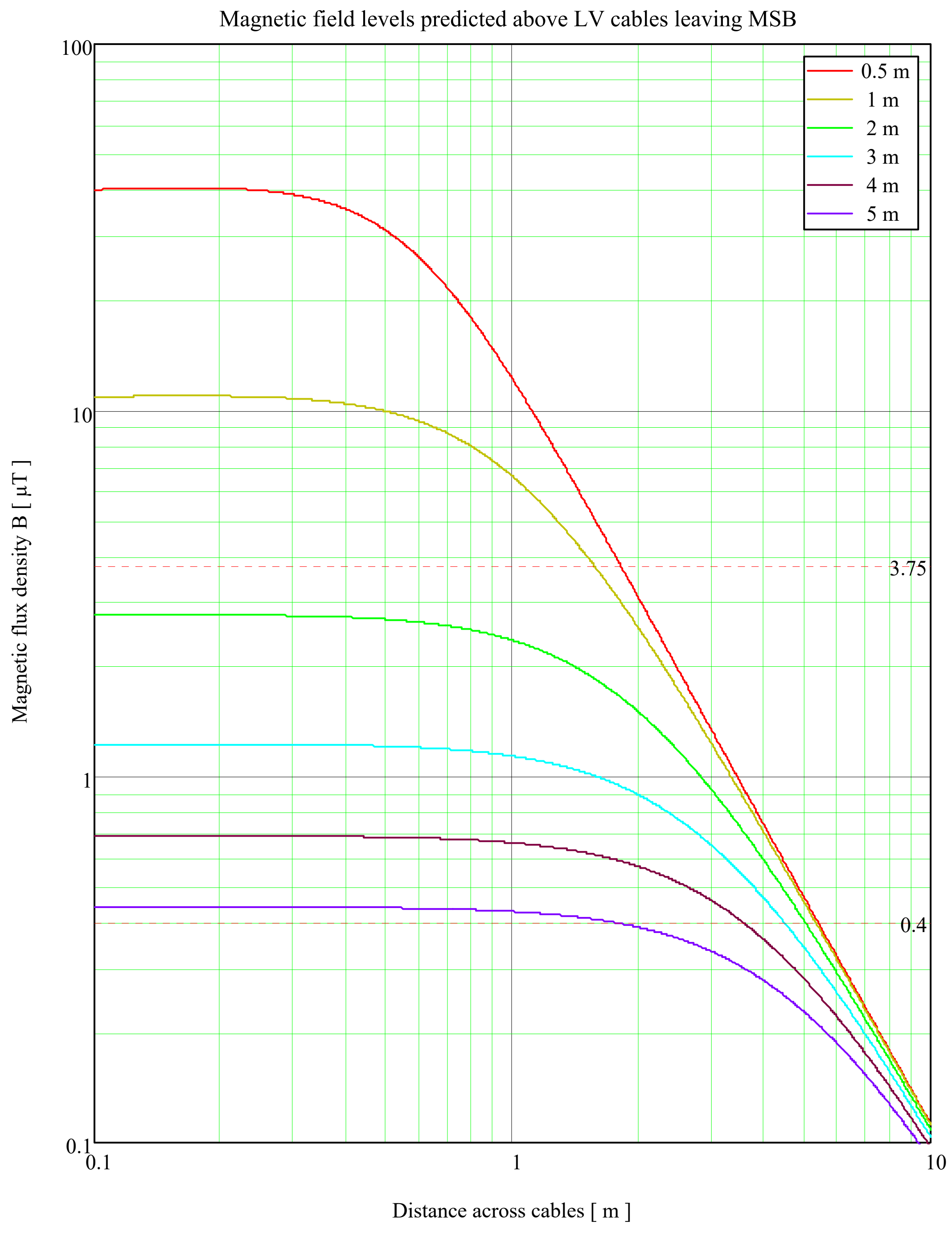


Fig 4b. Magnetic field generated above/under LV cabling leaving MSB (max. expected).